

Instrumentation Division

Microelectronics

Development of Application Specific
Integrated Circuits (ASICs) for DOE/BNL
Experimental Research Programs

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Presentation to the DOE NP Program Review

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Instrumentation Division

Mission

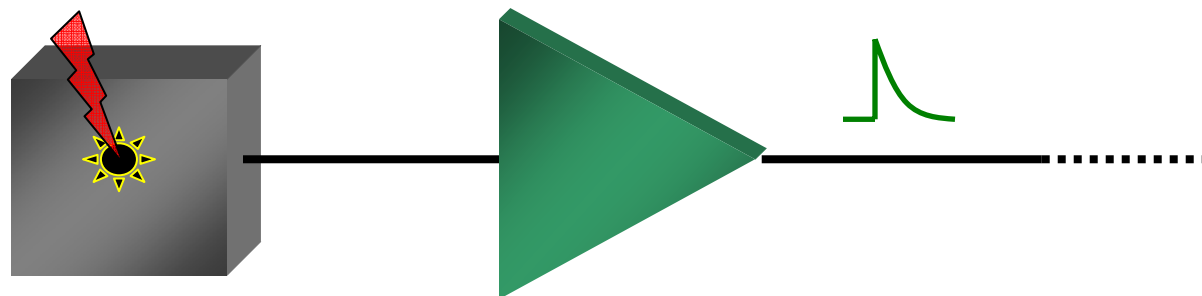
Develop state-of-the-art instruments for experimental research programs at BNL

Core Technologies

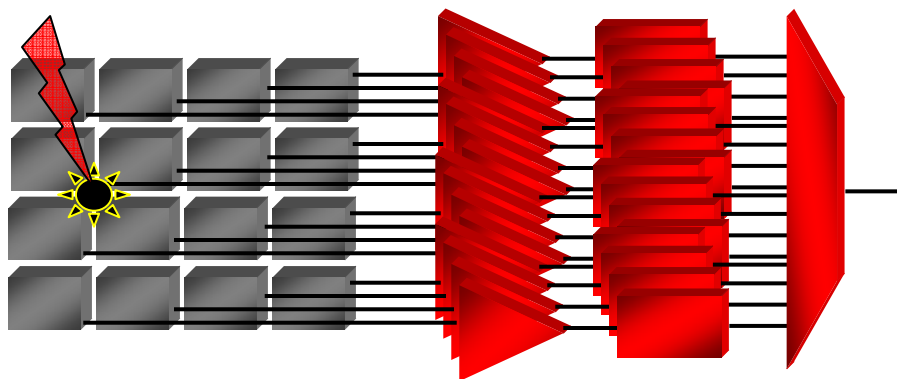
- **Semiconductor Detectors**
- **Gas and Noble Liquid Detectors**
- **Lasers and Optics**
- **Micro / Nano Fabrication**
- **Microelectronics**

From Electronics to Microelectronics

Electronics for radiation detectors consists of low noise readout of the signals generated in the sensor by ionizing radiation



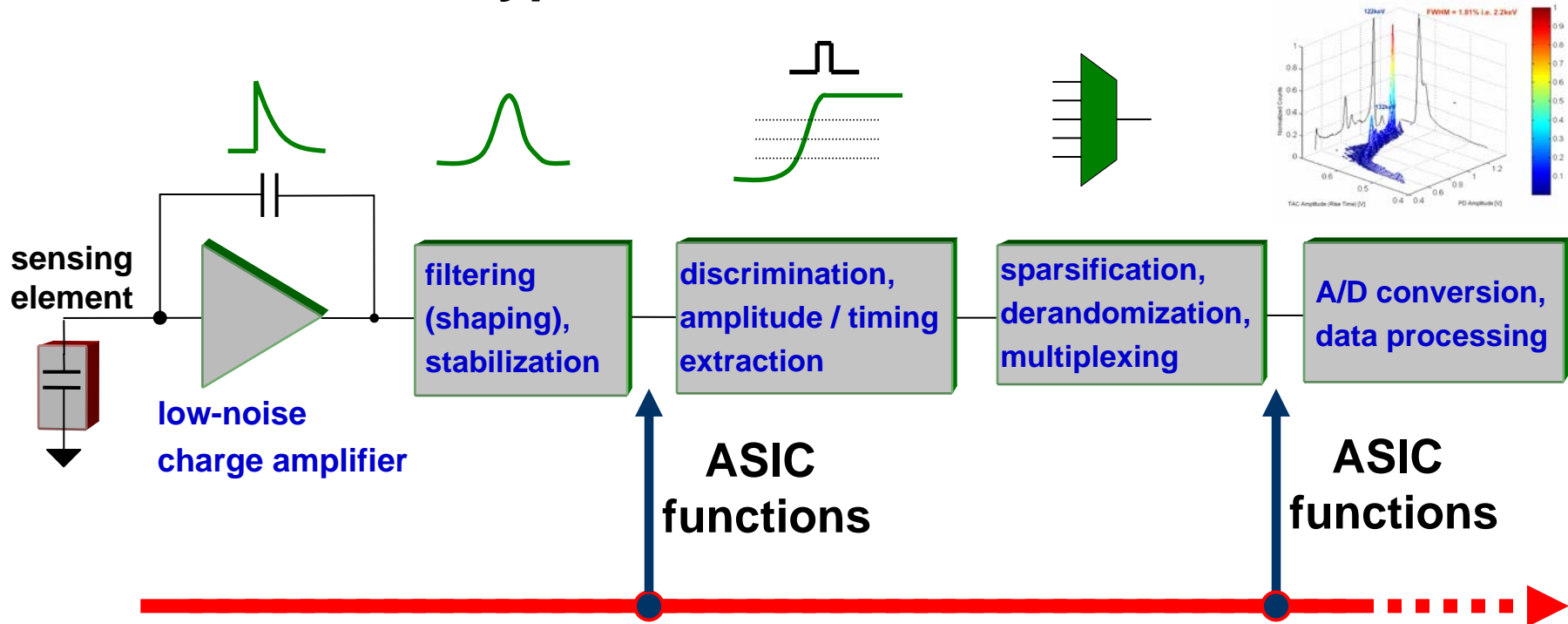
Low density, low functionality → discrete electronics



High density, high functionality → integrated circuits
(e.g. RHIC requires very high track density)

Integration

Typical electronics channel



year 2000

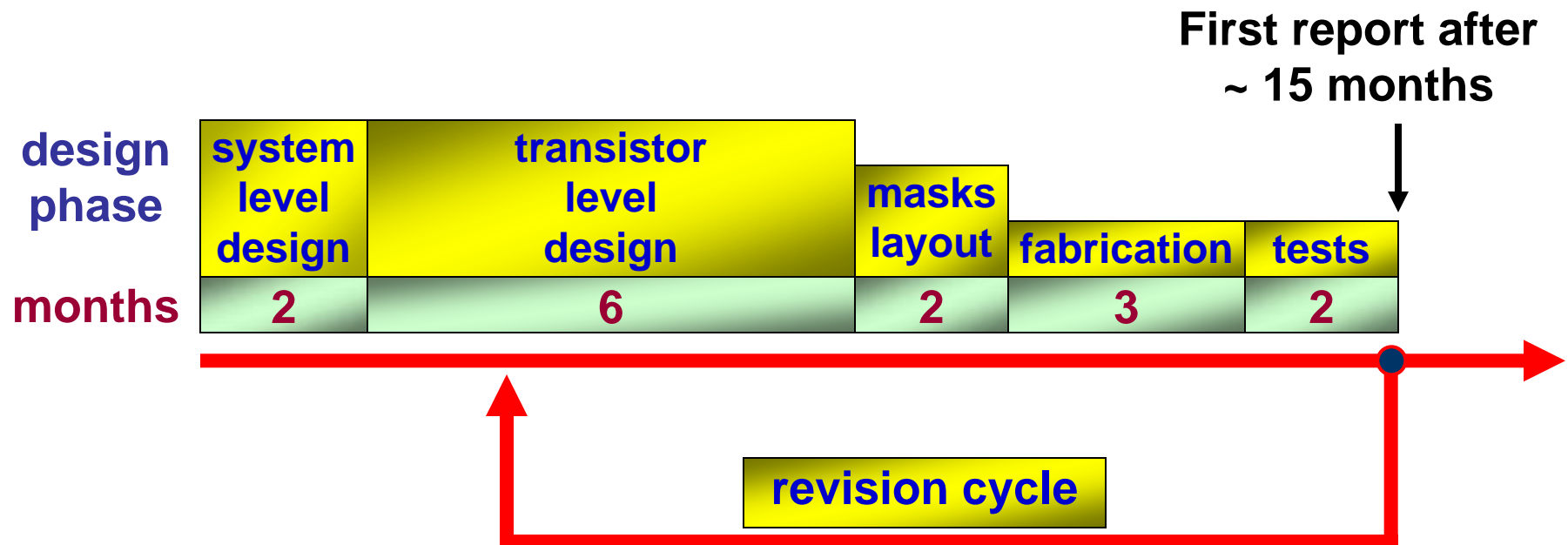
- 0.5 μm technology
- 16,000 transistors
- 16 channels
- analog

year 2006

- 0.18 μm technology
- 600,000 transistors
- 128 channels
- analog and digital (mixed-signal)

ASIC Design Flow

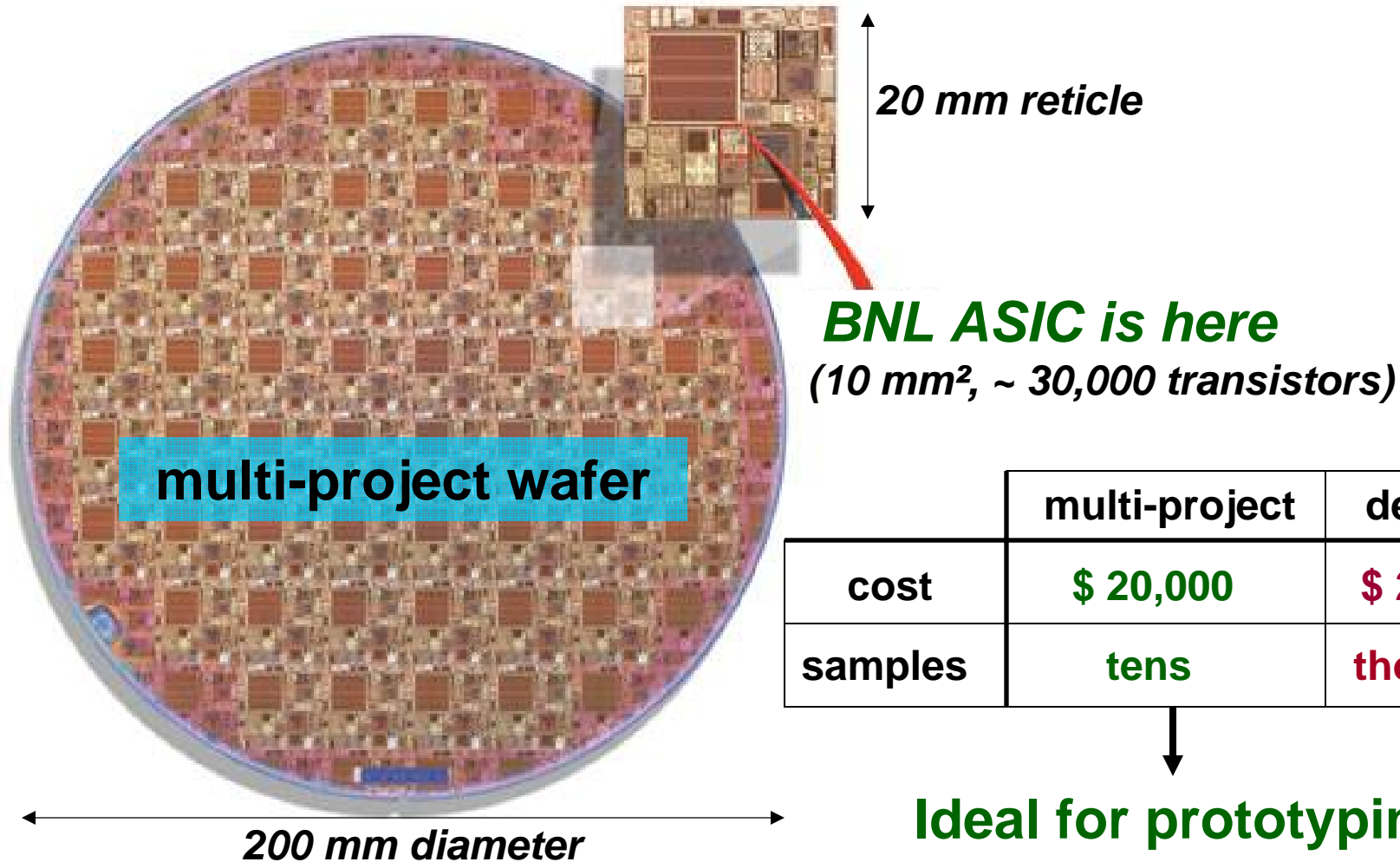
**Higher complexity means more resources
and expertise, longer development time
and ultimately higher risk**



**From concept to ready-for-production:
2 - 3 years (depending on complexity)**

ASIC Fabrication

Major foundries accept designs from multiple customers



	multi-project	dedicated
cost	\$ 20,000	\$ 200,000
samples	tens	thousands

↓
**Ideal for prototyping
and low volume**

About our group

**We have an established worldwide
reputation as leaders in low-noise ASIC design**

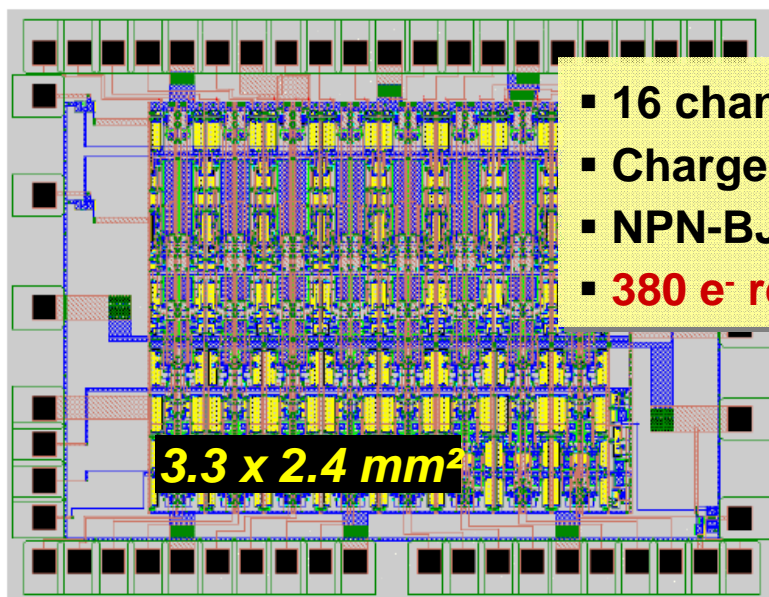
**In the last 10 years we developed more than 30 ASICs
for applications in:**

- **Particle and Nuclear Physics**
- **X- and Gamma-Ray Spectroscopy and Imaging**
- **Medical, Security, Industrial**

Some recent examples ...

Front-End ASIC for the STAR SVT at RHIC

A 240 Channel Multi-Chip Module for Readout of Silicon Drift Detectors

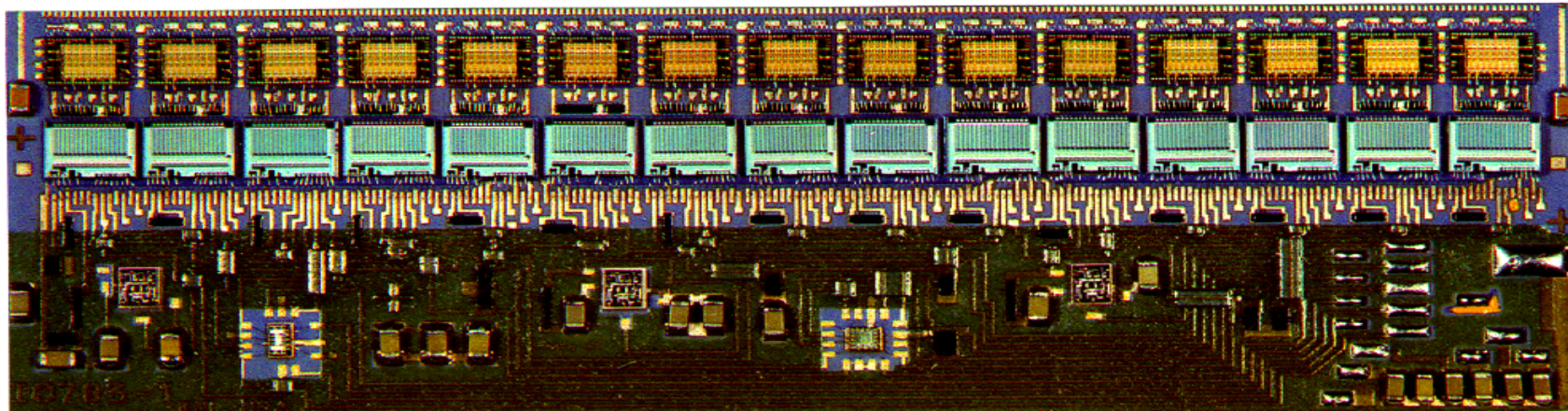


- 16 channels, 3.8 mW/channel
- Charge amplifier and shaper
- NPN-BJT process
- **380 e⁻ resolution at 50 ns**

3.3 x 2.4 mm²

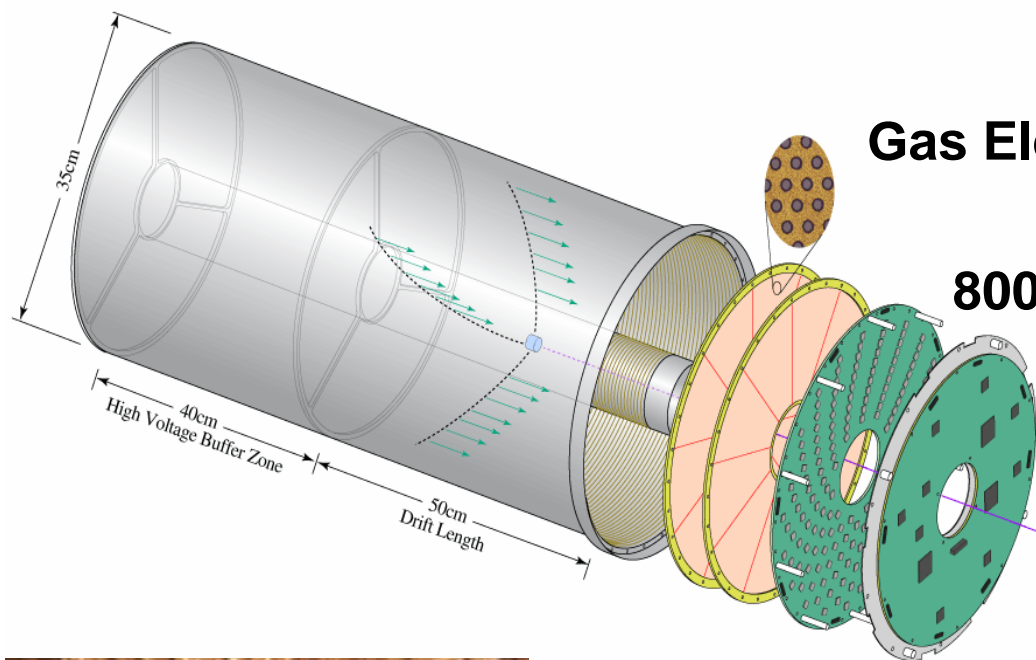
D. DiMassimo et al.

- 30,720 pixels (128 modules)
- 240 channel multi-chip module
- **PASA and SCA ASICs**
- **10-bit DR, 3 ns timing resolution**



D. Lynn et al.

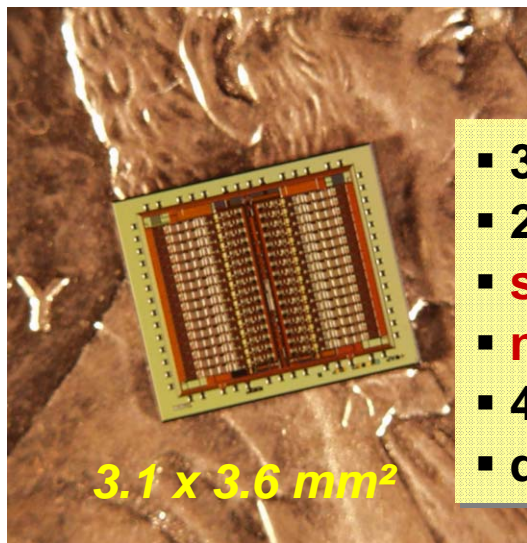
ASIC for the Laser Electron Gamma Source TPC



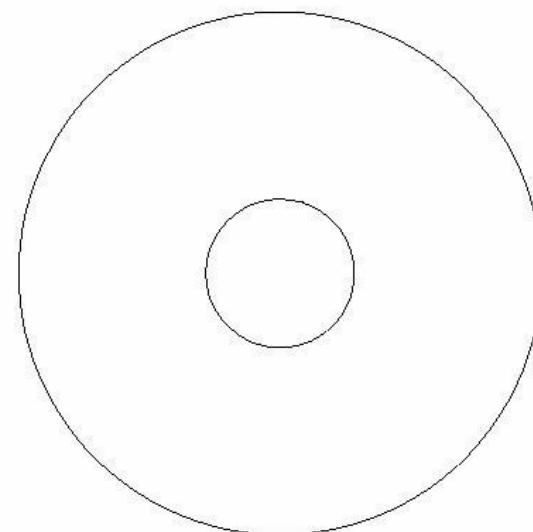
Gas Electron Multiplier

8000 anode pads read out in less than 400 μs due to unique sparse readout

Charged Pion production



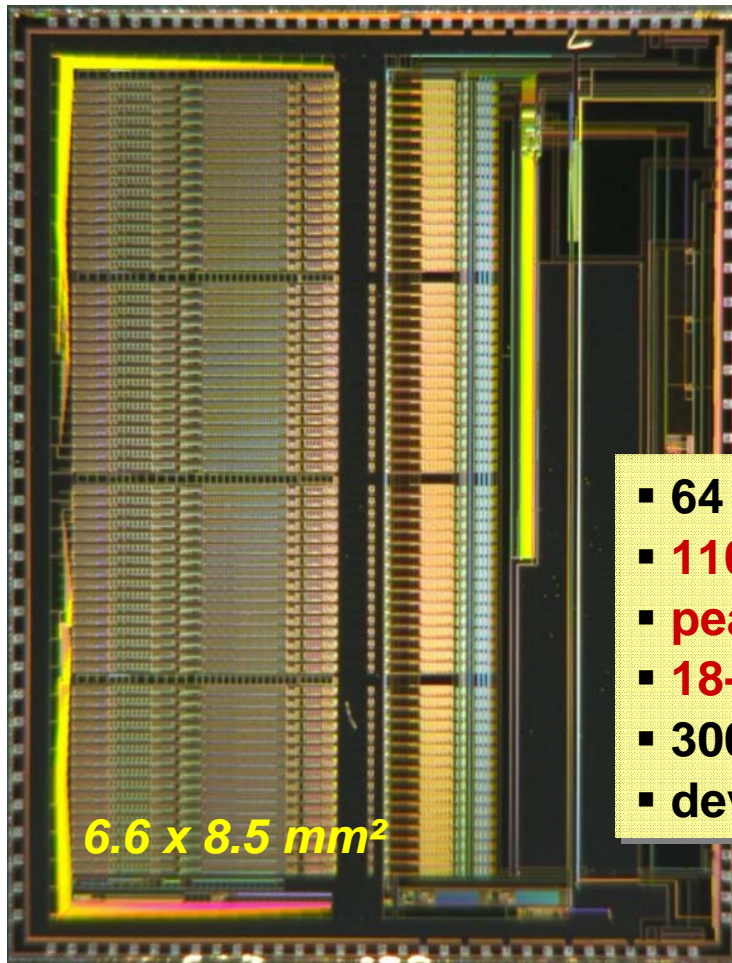
- 32 channels
- 230 e^- , 2.5 ns resol.
- **sparse readout**
- **neighboring**
- 40,000 transistors
- dev. time: 16 months



ASIC for Spallation Neutron Source Instruments

Unity-Gain ^3He Gas Detector for Small Angle Neutron Scattering

40,000 anode pads, each 25 mm², global rate 10⁸ n/s

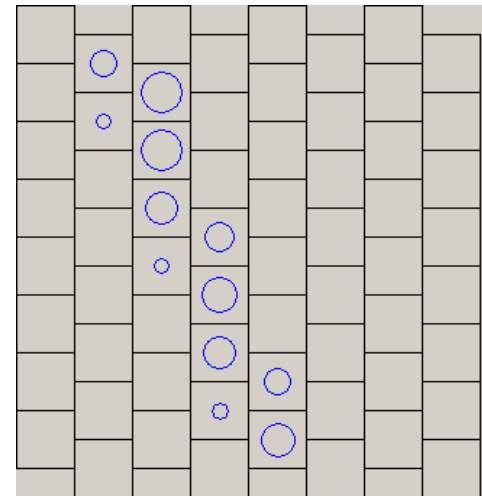


6.6 x 8.5 mm²

Count rate capability two-orders of magnitude greater than any existing instrument due to unique design, combining unity gas-gain and low-noise ASIC

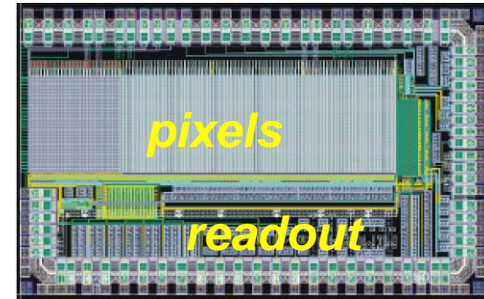
- 64 channels
- 110 e⁻, 1.5 mW/ch.
- peak detector ADC
- 18-bit timing
- 300,000 transistors
- dev. time: 20 months

test of 8x8 pad with α particles

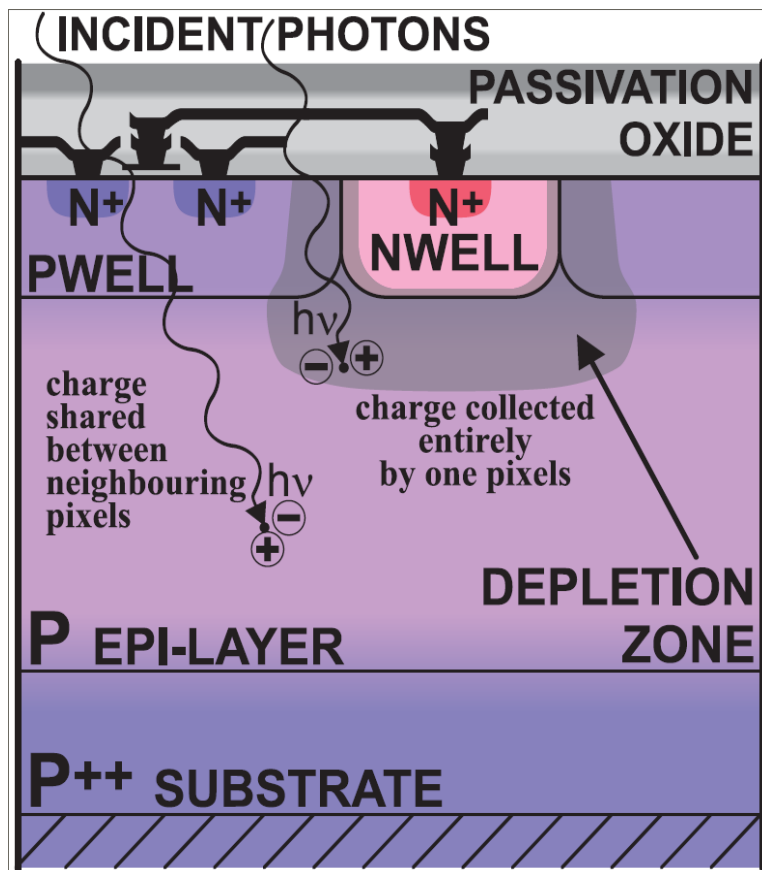


Monolithic Active Pixel Sensors (MAPS)

Sensor and readout in single entity for high-density (mega-pixel) applications (e.g. STAR Vertex Detector at RHIC)



G. Deptuch et al.



← MAPS in commercial CMOS

Good radiation tolerance and low-cost but poor Charge Collection Efficiency (few hundreds electrons spread by diffusion among several pixels in hundreds of nanoseconds → impact on S/N !)

Research to improve CCE

- Drift assisted collection (BNL LDRD)
- Silicon-on-Insulator (BNL-FNAL)

ASICs for Synchrotron Applications



- 32 channels front-end
- sub-20 electrons resolution
- spectroscopy, photon-counting
- high-rate
- 180,000 transistors



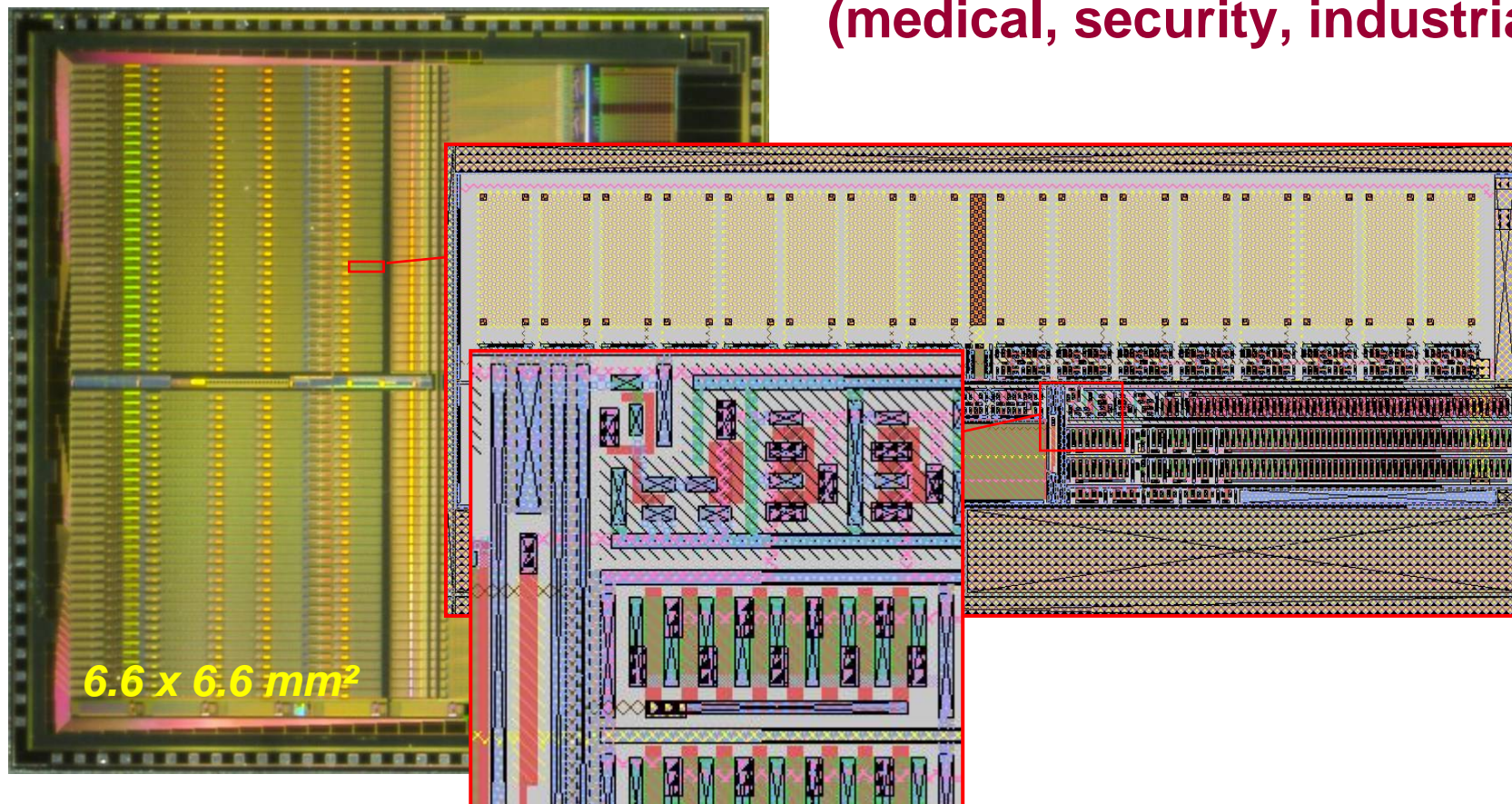
- 32 channels processing
- peak detection, sparsification, derandomization, multiplexing
- energy, timing and address
- high rate
- 36,000 transistors

For high-rate high-resolution spectroscopy and photon-counting experiments at NSLS and NSLS-II (EXAFS, powder diffraction, fluorescence microprobes)

ASICs for Cadmium Zinc Telluride (CZT) Detectors

We provide ASICs to all CZT-related research in BNL and to major CZT industries

ASIC for ultra-high-rate photon counting applications
(medical, security, industrial)

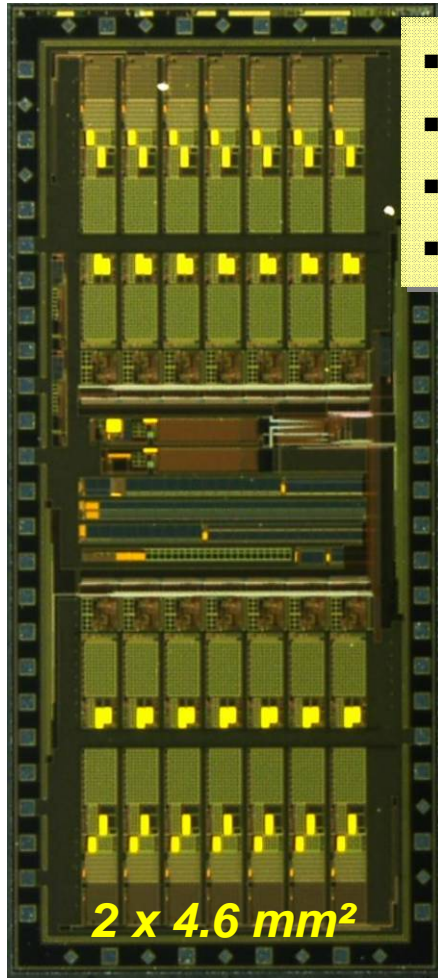


G. De Geronimo et al., NSS (2006)

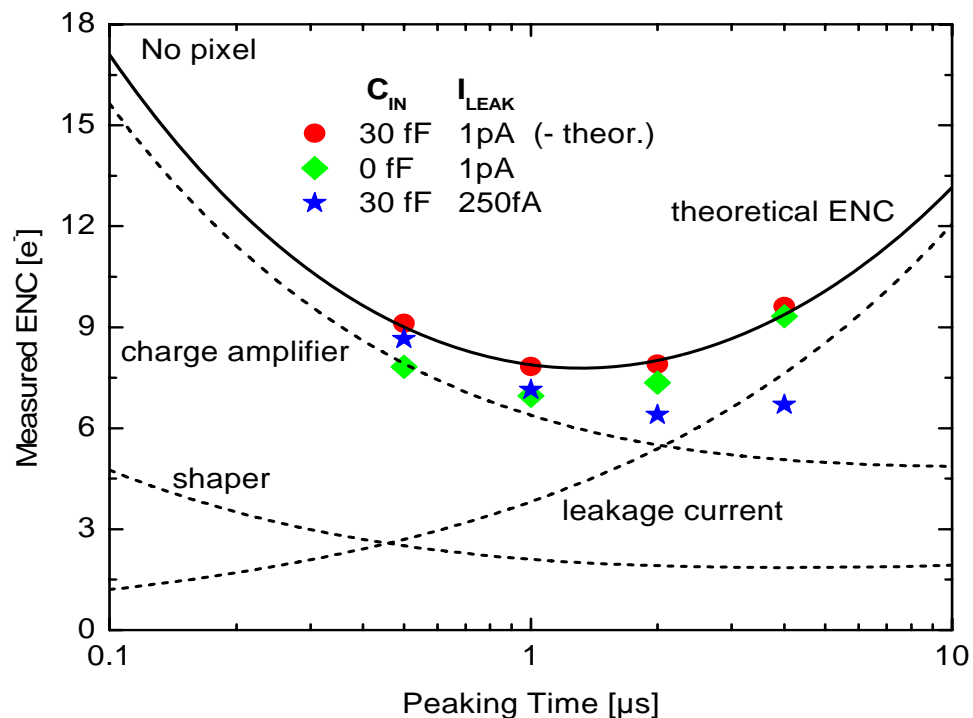
Ultra-Low Noise ASIC High Resolution X-Ray Spectroscopy

Collaboration with NASA at Moon Elemental Mapping

15 mm² Semiconductor Drift Pixels, 500 cm²



- 14 channels, 1.2 mW/channel
- sub-10 electrons resolution
- peak detection and sparse readout
- 30,000 transistors, dev. time: 15 months



Other ASIC Projects

- **STAR at RHIC:** CMOS Front-End for Silicon Vertex Tracker
- **PHENIX at RHIC:** Front-End and Flash ADC for Time Expansion Chamber (TEC)
- **ATLAS:** Cathode Strip Chamber (3 ASIC), Calorimeter Upgrade (SiGe), TEC
- **LBNL:** Ionization Imaging Chamber (Dave Nygren)
- **UNM:** Dark Matter (Dinesh Loomba)
- **SLAC:** Scattering Experiments at Linac Coherent Light Source
- **NSLS & AUSTR. SYNCH.:** High-Rate, High-Resolution Micro-Spectroscopy
- **NSLS & NJIT:** High-Rate, High-Resolution X-Ray Spectroscopy,
X-Ray Holography and Material Education
- **NRL:** Compton Imager (DHS), X-Ray Navigation System (NASA)
- **MEDICAL and SECURITY:** Micro-PET for RatCAP, PET-MRI, and
Wrist Scanner (BNL), CZT Based PET (BNL), 3D Position Sensitive
Detectors (UM, DHS), Co-planar Grid CZT Detectors (LANL)
- **CRADA:** eV Products (CZT), Digirad (Medical), CFDRC (MAPS),
Photon Imaging (Silicon), Symbol Technologies (Wireless)
- our patented circuit solutions are licensed to industries -